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MicroGPIPER Implementation Guide

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The total cost of corrosion at Army facilities is a significant percentage of maintenance and repair budgets. Corrosion of underground steel pipelines used to transport and distribute natural gas often leads to property and environmental damage, and loss of valuable resources. When corrosion problems occur, facility managers must decide to repair or replace pipes. These decisions frequently consider only current needs and are often made on the basis of limited knowledge about the corrosion status of the network.

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FOREWORD

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COL Daniel Waldo, Jr., is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Underground steel pipelines are commonly used to collect, transport, and distribute natural gas and petroleum products on Army installations. Pipe leaks and failures must be minimized in such systems to prevent property and environmental damage, and loss of valuable resources. The most common type of failure in buried pipe is caused by soil-side corrosion. When such failures occur, Directorate of Engineering and Housing (DEH) facility engineers must decide whether to continue repairing leaks as they occur, to install cathodic protection, or to replace failed pipe with new steel or plastic pipe. MicroGPIPER is a tool that can assist in this decisionmaking process to help prioritize the allocation of limited maintenance and repair dollars for underground gas distribution networks. This computerized maintenance management system helps schedule pipes for repair, and analyzes maintenance alternatives based on predicted corrosion rates and life cycle cost analysis. MicroGPIPER also predicts corrosion rates based on soil chemistry data and other physical properties of the piping network.

Objective

The objectives of the MicroGPIPER system are to (1) use soil and pipe parameters to predict and prioritize corrosion status of the pipes, (2) develop a state-of-the-art inventory system to record historical pipe data, (3) provide a usable repository for maintenance records, and (4) provide an economic analysis package for underground gas-piping networks in a user-friendly, easy-to-learn format.

Approach

State-of-the-art corrosion prediction and management techniques were investigated. Mathematical models used by the gas and petroleum industry were modified to develop a pipe corrosion rate prediction methodology and a numerical corrosion status index (CSI). Concepts for a corrosion management system were developed. A computerized system was developed in a user-friendly database format using the management concepts, corrosion prediction models, and life-cycle cost analysis methods.

Mode of Technology Transfer

It is anticipated that distribution, support, and maintenance of the MicroGPIPER program will be transferred to the U.S. Army Engineering and Housing Support Center, Fort Belvoir, VA.

2 THE MICROGPIPER SYSTEM

Overview

MicroGPIPER is a gas piping maintenance management program designed for use by the DEH at Army installations. The objective of the program is to assist facility managers in prioritizing the allocation of maintenance and repair funds for gas distribution networks. MicroGPIPER includes a piping system inventory, a mathematical corrosion prediction model, and a series of informative and analytic reports. The gas piping network is divided into a series of sections. Physical pipe data and soil chemistry data for each section is collected and stored in MicroGPIPER's inventory database. The reports may then be used to prioritize pipes for repair or replacement based on the corrosion rate prediction. The system will provide information to assist in budgeting repairs to the affected pipes.

Although designed for use on military bases and government installations, the MicroGPIPER program may find application in other areas. Municipalities and gas distribution and transmission companies may derive many benefits through application of the program to their own operations. This manual contains specific information intended for use by the DEH at Army installations. Other users may modify or ignore the building category codes and mission priority codes, which are specific to the Army. A routine in the System Utility allows editing the codes to customize the program for other users; however, the user may not assert any proprietary rights to MicroGPIPER or any edited version thereof.

When fully implemented, the MicroGPIPER program will assist DEHs to pursue a cost-effective maintenance strategy for avoiding hazardous gas leaks and to reliably forecast future funding needs. The program provides current reports and future projections on the corrosion status of the piping networks. The present worth of maintenance programs can be calculated for comparison of different strategies. The MicroGPIPER program is a user-friendly, straightforward collection of field implementation procedures. MicroGPIPER is written in the CLIPPER compiler language, a dBASE III Plus and dBASE IV compatible compiler that produces an executable program that does not require the use of dBASE software.[1] The program uses pop-up help screens and interactive prompts to assist the user in entering data and producing reports. This ease of use will allow personnel to quickly master the program and to gain benefits quickly for a small investment of time and energy. The user-friendly features are balanced by the ability to add passwords for restricting access to databases and to prevent inadvertent loss of data.

Program Philosophy

In general, maintenance and repair options can be classed as either reactive or proactive. It is reactive to wait for a failure or problem, and then to select a maintenance alternative, usually the quickest, easiest, emergency repair. This approach ignores long-term planning and fails to recognize developing problems. One reason this approach persists is that the condition of the piping network is not visible. Underground piping is not easily accessible, and there is no method for quantitatively evaluating its condition.

MicroGPIPER proactively uses current and predicted future condition ratings in combination with a life cycle cost analysis to assist in developing a maintenance and repair strategy. MicroGPIPER helps to prioritize maintenance projects and to pinpoint trouble spots. Information generated by MicroGPIPER can help to devise a maintenance strategy that addresses current needs and also deals with projected needs and problems.

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[1] CLIPPER is a registered trademark of the Nantucket Corp., Los Angeles, CA. dBASE is a registered trademark of Ashton-Tate, Torrence, CA.

The MicroGPIPER program introduces a forward-looking management system philosophy to the maintenance of gas pipe systems. The ability to predict the probable failure of a specific pipe section enables facility managers to develop a planned maintenance strategy for the system. Sections of pipe that have approached the end of their useful life may be analyzed to determine the most cost-effective repair/replacement strategy. MicroGPIPER also helps to develop a budget forecast for planning maintenance expenditures.

Data Required by MicroGPIPER

MicroGPIPER divides a pipe into pipe sections, using a separate record or set of data for each section of the same pipe to account for different soil resistivity and last-repair dates of pipe sections. For each identified pipe section, MicroGPIPER maintains one record in its "pipe section database" containing the pipe's physical properties, installation date, and surrounding environment (i.e., soil). MicroGPIPER also maintains a "repairs database" for each pipe section (one record for each repair of the section) and records data in a "valves database" on pipe section valves (one record for each valve).

The MicroGPIPER program uses soil chemistry data and other information to predict the useful life of underground gas piping. Soil sampling must be performed to provide MicroGPIPER with the data it needs to predict the condition of an existing pipeline or to assess the corrosion characteristics of a proposed line. A map of the gas system must be obtained to determine and assign ID numbers to each pipe section. Each pipe ID number will refer to a section of pipe less than 1000 ft* in length not intersected by another pipe. Individual service connections to single residences may be excluded so that a pipe section may service several houses. Larger diameter service lines may be included as an additional pipe section. In addition, historical information must be gathered. All procedures presented in this guide are based on field tests performed at military bases.

The corrosion model used in MicroGPIPER requires data on the following parameters:

- pipe material
- thickness of pipe
- age of pipe
- coating type
- soil moisture
- soil resistivity
- pH of soil
- chloride content of soil
- sulphide content of soil
- record of reported first leak
- structure-to-soil electrical potential with respect to Cu-$CuSO_4$ reference cell.

From this data, the program calculates the expected life of the pipe and the current condition of the pipe. The state of the corrosion affecting a pipe section is expressed as the Corrosion Status Index (CSI).

The MicroGPIPER Corrosion Status Index and Prediction Models

The Corrosion Status Index

Based on records gathered from numerous underground gas piping systems, corrosion of the exterior of the pipe alone is responsible for half of all pipeline leaks. Corrosion also contributes to breaks

* 1 ft = 0.305 m.

attributed to mechanical factors such as heavy traffic, construction activity, improper bedding, and other mechanical stresses.

MicroGPIPER provides a measure of the pipe condition, the CSI, which predicts the damage of the pipe due to corrosion. Such damage is ordinarily measured by inspection. Because of the expense of such dig-ups, far fewer dig-ups than needed are typically done, and maintenance personnel work with incomplete knowledge of pipe condition. MicroGPIPER computes the corrosion status index based on corrosion theory and the data it has on the physical properties, age, and environment of the pipe. Because pipe damage due to corrosion is affected by variables that are difficult to measure, such as the presence of cinders or trash in the backfill, or abrasions to the pipe surface caused during installation, the CSI can only provide a rough estimate of pipe condition; it is not meant to entirely replace visual inspection. Rather, it can be used when visual inspection of pipes is impractical, to determine which pipes should receive further attention, and to predict future pipe condition.

The CSI is a dimensionless number with a scale of zero to 100, where an index of 100 represents a new pipe with no corrosion and an index of zero represents a completely deteriorated pipe. Piping with a CSI approaching zero has little useful life left and a high failure/leak rate, and should be replaced when the economics of repair and maintenance indicate new pipe is needed. It has been formulated empirically that the first leak occurs when the CSI equals 30. The ability of MicroGPIPER to calculate current CSI and to project future CSI values for the remaining life of a pipe section is the key to this management system.

Calculation of the Corrosion Status Index (CSI)

The prediction of damage to metals due to corrosion has received considerable study. MicroGPIPER's model for prediction of pipe condition is based on a number of such studies,* as well as on a statistical analysis of data on leaking pipes.

The CSI is defined as:

$$CSI = 100 - 100(P_{av}/T) \qquad \text{[Eq 1]}$$

where:
P_{av} = average corrosion pit depth of a section of the pipe
T = original wall thickness of the pipe.

It has been observed[3] that:

$$P_{av} = 0.7P_{max} \qquad \text{[Eq 2]}$$

where P_{max} = the maximum corrosion pit depth of a section of pipe.

The pipe will experience its first leak when $P_{max} = T$. By substituting this into the above equations, it can be seen that the CSI will be 30 at the time of first leak. The CSI is given by the following relationships:

If Age = Years-to-First-Leak, then CSI = 30.

If Age < Years-to-First-Leak, then

$$CSI = 100 - 70\ (Age/\ Years\text{-}to\text{-}First\text{-}Leak)^{0.58}$$

* See the "Uncited References" on p 32.

[Note: The 0.58 exponent is based on East Ohio Gas Company's finding that the percent of wall thickness degradation due to corrosion is proportional to $t^{0.58}$ where t = time.][2]

If Age > Years-to-First-Leak, then

$$CSI = 30 - 10(\text{Log}_{10}\text{Number of Leaks})$$

where:

Age = age of the pipe in years at the time of interest

Years-to-First-Leak = the predicted age of the pipe when it experiences its first leak as forecast by the model explained below

Number of Leaks = the cumulative predicted number of leaks as forecast by the model described under "Determination of Number of Leaks After First Leak."

The MicroGPIPER Years-to-Leak Prediction Equation

The Warren Rogers Study. The prediction equation used in MicroGPIPER is based on Warren Rogers' equation for predicting the date of first leak for underground steel tanks,[3] because the same corrosion processes attack the soil side of both underground steel tanks and pipes. Essentially, a pipe can be viewed as a long, thin tank. The Warren Rogers study is one of the most extensive studies to date of underground steel tank corrosion. The Warren Rogers equation was developed from a subset of data from a study, that included approximately 10,000 sites throughout the United States and Canada. Warren Rogers' equation is:

$$AGE = 5.75R^{0.05}S^{-0.018}e^{(0.13pH - 0.41M - 0.26Su)} \qquad \text{[Eq 3]}$$

where:

AGE = average age at which a tank in such conditions undergoing localized corrosion will leak

R = soil resistivity in ohm-cm as measured in the laboratory using a soil sample taken at the structure depth and saturated with distilled water

S = tank capacity in gallons

pH = soil pH

M = 1 if soil is saturated

= 0 otherwise

Su = 1 if sulfides present

= 0 otherwise.

The MicroGPIPER model was developed by modifying the Warren Rogers equation for the specific case of gas piping.

The Effect of Wall Thickness. The Warren Rogers model includes a tank size term "S". The analog of this in piping is the pipe wall thickness. The wall thickness term in the MicroGPIPER prediction is based on Melvin Romanoff's equation[4] for predicting the maximum corrosion pit depth of a pipe. Romanoff's equation for maximum pit depth can be rearranged to predict the Years-to-Leak for a pipe based on pipe wall thickness and soil type, taking the form:

$$YTL = cT^n \qquad \text{[Eq 4]}$$

2 *Procedures for Evaluating Pipeline Replacement* (East Ohio Gas Company, Cleveland, OH, 1979), p 86.

3 Warren Rogers Associates, *Report by Special Task Force on Underground Storage Tanks* (Petroleum Council for the Protection of Canadian Environment, Ottawa, 1980), p C1.

4 Melvin Romanoff, *Underground Corrosion*, National Bureau of Standards Circular 579 (National Bureau of Standards, Gaithersburg, MD, 1959).

where:

YTL = number of years from installation date to first leak for a pipe
T = pipe wall thickness
n = a constant value based on soil type.

MicroGPIPER uses this form for the wall thickness term, but substitutes the average of all possible soil-type values for n. Users do not provide GPIPER with soil type information, and the best correlation was found by using the average of Romanoff's soil type value in prediction. This average value for n is 2.7.

Development of the Model Using Gas Pipe Leak Data. To further refine the model for the case of gas piping, a statistical analysis was performed on data for 98 leaking underground steel gas pipes.[5] Warren Rogers[6] found that approximately 77 percent of underground steel structures in a random sample such as this will experience localized corrosion, so the prediction was developed for these "worst case" pipes. Information on the data used for developing the prediction is summarized in Table 1. The minimum, maximum, and mean values for each parameter in the data set are given. Application of the model to cases outside of these ranges may not be valid. The constants for the model were developed using least squares linear regression, and the analysis assumes that the lifetimes of pipes fit a normal distribution.

The gas pipe data set was used to determine a threshold value for the soil moisture (expressed as a percent). For values below the threshold, the boolean variable M will be set to 0, and for values above the threshold M will be set to 1. The Warren Rogers model uses a criterion of soil saturation to set this variable; however, it was desired to quantify this as a percentage to facilitate its use in the program. The gas pipe data was analyzed, and the moisture threshold which provided the "best fit" to the data was found to be at 28 percent. This value is consistent with corrosion theory, since by the time moisture levels reach 30 to 35 percent, further moisture increases affect the resistivity significantly less.

The data set was also used to determine a threshold value for soil sulfide concentration. The threshold was found to be 0.5 ppm, which is extremely low. This means that the presence of sulfides in almost any concentration will increase the corrosion rate. A simple test for the sulfide concentration that reveals only the presence or absence of sulfides is sufficient.

Table 1

Summary of Gas Pipe Data Used for Model Development

Parameter	Sample Mean	Sample Minimum	Sample Maximum
Wall thickness (in.)	0.251	0.14	0.6
Soil resistivity (ohm-cm)	1827	61	6800
Soil pH	7.3	4.1	9.7
Soil sulfide concentration (ppm)	2.8	0	128
Soil moisture (%)	25.5	5.8	42.2
Pipe age at leak (years)	35	7	68

[5] John Hogan, East Ohio Gas Company Leak Data (1987).
[6] Warren Rogers, p 5.

The least squares linear regression yielded the following expression for Years-to-Leak (YTL):

$$YTL = 25.2 + 45.9R^{0.05}T^{2.7}e^{(0.13pH - 0.41M - 0.26S)} \quad \text{[Eq 5]}$$

where:

YTL = years to leak
R = resistivity of the soil (ohm-cm) as measured in the laboratory using a soil sample taken at the structure depth and saturated with distilled water
T = pipe wall thickness (in.)
pH = pH of the soil
M = 1 if the soil moisture content is above 28%
= 0 otherwise
S = 1 if the soil sulfide content is above 0.5 ppm
= 0 otherwise.

This expression has a standard error estimate of 5.5 years and a multiple correlation coefficient (R^2) of 0.54. It was observed that while the least squares line keeps the residual sum of squares at its lowest, the largest concentration of observations (the mode value) lies approximately one-third of the standard deviation of the residuals (1.7 years) below this line. Thus, because we prefer to be conservative and under-predict the life of the pipe rather than over-predict, we use the mode value (23.5) instead of the mean value (25.2) as the intercept of the equation.

The resulting prediction equation used in MicroGPIPER is:

$$YTL = 23.5 + 45.9R^{0.05}T^{2.7}e^{(0.13pH - 0.41M - 0.26S)} \quad \text{[Eq 6]}$$

where the variable definitions are the same as those for Eq 5.

The Effect of Cathodic Protection

The Years-To-Leak (mode value) prediction equation used by MicroGPIPER is for pipe that is not cathodically protected. In theory, a pipe that is properly cathodically protected should not experience a corrosion-induced leak. Thus the Years-to-Leak should be infinite in number. In practice, however, cathodically protected pipes do leak. The Time-to-First-Leak should be longer if a pipe is cathodically protected than if unprotected. The extension of time to first leak achieved by a cathodic protection system depends on the quality of the system. The number of years until the first leak for a cathodically protected pipe should therefore fall between infinity and the number of Years-to-First-Leak for the pipe if it were unprotected.

Because MicroGPIPER does not take sufficient user information to estimate the effect of a particular cathodic protection system, it instead does the following. For a cathodically protected pipe, MicroGPIPER first computes the Years-To-First-Leak for an unprotected pipe. It then makes two predictions of Years-To-First-Leak: (1) the prediction for an unprotected pipe, and (2) infinity (that the pipe will not leak). Two CSI values are computed for the pipe for each year in the future, one based on each prediction of Years-To-First-Leak. MicroGPIPER projects that the actual CSI values for future years will fall between those of the two predictions. MicroGPIPER uses the worst-case (shortest) prediction of Years-To-First-Leak in subsequent computations.

The Effect of Coatings

Pipe coatings are beneficial when used in conjunction with properly operated cathodic protection systems, as they reduce both the amount of current required to protect the pipes and the average rate of uniform corrosion. However, where cathodic protection is poor or nonexistent, coatings frequently increase the rate of pitting and thus reduce the time to first leak. The reason for this increased pitting rate is that pipe coatings have small imperfections (holidays) that expose part of the pipe to the surrounding environment. These small areas become anodic to the rest of the pipe or other metallically connected structures, giving the pipe small anodes and large cathodes. Pitting occurs rapidly at the anodes.

While it is difficult to put a precise proportion on the time to first leak for coated vs. uncoated (bare) pipe, experienced corrosion engineers[7] confirm that 0.67 is a good empirical estimate. That is, a coated pipe without cathodic protection lasts (remains leak-free) only two-thirds as long as a similar bare pipe in the same environment. Therefore, for a coated pipe, MicroGPIPER first computes the predicted number of Years-To-First-Leak for a bare pipe and then multiplies this prediction by 0.67. This is completely an empirical number.

Determination of Number of Leaks After First Leak

MicroGPIPER generates a prediction of the number of leaks that can be expected to occur in each pipe section annually after the first leak. The prediction is based upon soil resistivity and gives the number of leaks that are predicted *per mile* of pipe. The prediction was developed from gas industry data[8] and is shown in Table 2.

Data Requirements

Some Army installations may not have all of the data that is called for by the MicroGPIPER prediction model and may not have the resources to collect it. The main influencing factors in the prediction models (years to leak and cumulative leaks) are the pipe wall thickness and the soil resistivity. The soil pH, moisture, and sulfide content influence the prediction to a lesser degree. Therefore, it is possible to obtain a reasonably accurate prediction by obtaining the pipe wall thickness and soil resistivity for all pipe sections, and simply measuring the pH, moisture, and sulfide content of the soil at a few representative locations at the installation.

Sampling of Pipes to Determine Actual CSI's

Sampling for dig-ups to determine actual CSI's consists of inspecting pipe conditions (measuring pit depths) at predetermined intervals on a pipeline section. Samples are chosen based on soil properties and age of the pipes. Two things are important in sampling: (1) spacing of inspections, and (2) size of area inspected. One statistical study by Romanoff[9] on a 25-mi[*] length of oil pipeline has shown that the true average pit depth remained within the average values, regardless of the number of inspection points. He inspected at intervals of 1/8, 1/4, 1/2, and 1 mi. For the pipelines being considered, 25 inspections at 1 mi apart gave an approximation of line conditions that was as good as one provided by 6384 inspections at 20 ft apart. Thus, one inspection per mile of pipeline is enough to determine the maximum pit depth. A large number of inspections, each of an area 1 ft long, is almost as representative as the numbers obtained when the entire joint was exposed. A comparison of the maximum pit depths for different starting points on 5-mi-long lines of equally spaced inspections showed that the average was independent of the starting point. Therefore, it is concluded that for each different soil, age, thickness, and each different pipe section, adequate sampling should consist of 1-ft exposure sections at interval spacings of 1 mi. Equation 1 can be used to calculate the actual CSI using the data obtained from such measurements.

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[7] Personal communication with Jim Bushman, Corrpro Corp., Medina, OH, and Ed Ondyke, Western Region Chief of the Office of Pipeline Safety, U.S. Department of Transportation, Washington, DC.

[8] East Ohio Gas Company, p 101.

[9] Melvin Romanoff, *Underground Corrosion*, National Bureau of Standards Circular 579 (1957).

[*] 1 mi = 1.61 km.

Table 2

Cumulative Leaks Prediction Table

Year*	2000 ohm-cm	5000 ohm-cm	8000 ohm-cm
1	3	2	2
2	5	4	3
3	10	6	4
4	18	9	5
5	29	12	6
6	46	16	7
7	71	21	8
8	109	27	9
9	167	34	10
10	248	43	11
11	378	54	12
12	573	67	13
13	803	82	14
14	1000	100	15
15	1000	121	16
16	1000	146	17
17	1000	176	18
18	1000	211	19
19	1000	250	20
20	1000	297	21
21	1000	350	22
22	1000	410	23
23	1000	487	24
24	1000	567	25
25	1000	660	26
26	1000	760	27
27	1000	860	28
28	1000	960	29
29	1000	1000	30
30	1000	1000	31

* "Year" indicates the number of years after the year of first leak. The remaining columns indicate the predicted cumulative number of leaks *per mile* of pipe buried in soil of the indicated resistivity.

Using This Guide

This guide presents a method for planning the implemention of the MicroGPIPER Program. Each step of the data-gathering process is described. Appendix A gives a detailed sample contract specification for program implementation. Recommended procedures for continuation of the MicroGPIPER Program are detailed including ongoing repair data collection.

To prepare for implementation of MicroGPIPER, it is best to become familiar with the program. The *MicroGPIPER User's Manual*[10] will assist in the process of loading the program and configuring the selected hardware.

[10] Richard C. Guglomo, Vicki L. Van Blaricum, C. David Page, Jr., and Ashok Kumar, *MicroGPIPER User's Manual*, ADP Report M-92/10 (U.S. Army Construction Engineering Research Laboratories [USACERL], January 1992).

Overview of the Implementation Process

There are several steps involved in implementing the pipe management system at an installation. These include:

- selecting a contractor for sampling
- collecting maps, drawings, and records
- identifying individual pipe sections
- developing a pipe section numbering (ID) key
- gathering the field data and samples
- entering the data into the program
- evaluating the data collected
- using the reports for future planning and budgets.

After the program is implemented, maintaining the database will require very little time, and the usefulness of the program will increase each year. The steps for implementing the program are described in the following chapters.

3 PLANNING THE PIPE CONDITION SURVEY

Selecting Sampling Contractors

A contractor with the personnel and equipment required to perform the sampling and the data entry must be selected. The necessary equipment includes:

- pipe locator device
- backhoe for initial removal of overburden
- shovels for removing sod and final uncovering of pipe
- pipe coating repair tape for use prior to reburial
- millivolt meter for measuring impressed voltage of cathodic protection system
- computer hardware for program, including storage capacity sufficient for the data input (at least 20 megabyte recommended).

It is difficult to predict the period of time required for the sampling procedure as sampling times vary due to differences in terrain, access, and other factors. During the field test at Fort Hood, TX, a total of 19 samples were collected, with 11 in 1 day. Weather may also delay sampling procedures. It is important not to sample in the rain because the analytical moisture content results obtained for the sample may not represent the actual moisture content of the soil in contact with the pipe.

Samples collected during field data gathering procedures must be sent to a laboratory for analysis. The parameters to be analyzed include:

- soil pH
- sulfides
- chlorides
- resistivity
- moisture content.

It is important that the laboratory selected be qualified to properly test for these parameters: it should be certified by the U.S. Environmental Protection Agency (USEPA) to ensure accuracy of the results.

The contractor qualifications include familiarity with piping systems and corrosion control, pipeline location and excavation, and general computer skills. The user-friendly features of MicroGPIPER preclude the need for highly skilled programmers, but regular computer usage will be a prerequisite for efficient data input. Data entry can be nearly complete prior to the field sampling; soil data may be entered last. In some instances, DEH personnel may be available to perform part of the implementation in the place of contractors. In other instances, complete implementation by outside contractors with minimal DEH supervision will be preferred.

Award/Kickoff Meeting

After selecting a contractor and testing laboratory, a scheduling meeting should be held. The contractor's job supervisor for the excavation work may want to collect samples in a definite order, to minimize travel and mobilization time. The backhoe may be driven short distances between sample sites, but longer moves will require loading the backhoe on a trailer or truck bed for transport. The contractor should be reminded of the weather restrictions.

Sufficient sample bottles and a cooler with blue chemical ice procured for sample storage and shipment should be obtained. Any special instructions from the testing laboratory should be discussed with the contractor so that valid samples are taken.

Contractor personnel in charge of record collection and data entry should attend the initial meeting. The computer needed for MicroGPIPER implementation may be procured by the DEH and provided to the contractor during the implementation. Alternately, the contractor could procure approved computer hardware and turn the equipment over at the end of the project when data entry is complete. The *MicroGPIPER User's Manual* contains specific requirements for hardware to run the MicroGPIPER program.

Collection of Maps, Records, and Drawings

One of the major components of a pipe condition survey is collection of documents. To develop a thorough understanding of the piping system under study, as much historic information as possible about the system must be gathered. Usually maps, installation records, and maintenance records of the piping system can be obtained from the maintenance department in charge of the routine upkeep of the system. The maps will be necessary also to determine the pipe sections and locate pipe branches. These documents are also valuable for determining locations at which the piping in the system will be sampled. Soil sample information is required for entry into the data entry fields of each pipe section in the MicroGPIPER program. Sampling every pipe section would take considerable time and effort. To enter all the pipe sections and begin using the program, soil conditions may be entered from samples taken at adjacent pipe sections. It should be noted in the Comment field that the soil data is not specific to the pipe section. The Comment 1 field could read, for example, "Soil data from Area 5, Section 3 used in lieu of actual data for this section." The implementor may choose representative pipe sections to sample based on the local topography and soil conditions. As-built drawings are sometimes stored in a regional plan facility or central DEH files, and it may require several weeks to receive the requested copies. Several items, along with possible sources, should be located and obtained in advance:

1. Maps of Survey Area
   a. Local Engineering Authority
   b. Base Engineering Plan Center
   c. Corps of Engineers District Office

2. Drawings of Pipe System
   a. Base Operations and Maintenance Division
   b. Installation Contractors' Offices
   c. Gas Utility Engineering Department

3. Pipeline Repair Records
   a. Base Operations and Maintenance Division
   b. Contractor/Subcontractor Records.

Gathering all the information available at the start of the implementation procedure will save time later on. Underground pipes are sometimes difficult to locate even with the best of maps and drawings. Until proper documentation is in hand, the field work and data entry into the program cannot begin.

A. Selecting Pipe Sections

The gas distribution system will be broken down into discrete sections of pipe for entry into the database. Pipe sections should be selected by the user during the initial preparation for the pipe condition survey. Since most underground piping systems are mapped in detail, initial pipe section designation may be done from existing drawings. Pipe sections are identified by the Pipe ID (10 characters) and the Section ID (four characters). A section is a subdivision of a pipe. This allows the Pipe ID number to be the same for all the pipe sections in a designated area, as long as their Section ID numbers are different.

The first step in defining pipe sections is to divide a map of the whole base or installation into discrete areas. Each area will correspond to a "Pipe ID." Each area should contain buildings of the sample type, or buildings used for the same purpose. For example, a hospital and surrounding clinics, doctor's offices, and pharmacies could be considered as a single area. The Pipe ID for all pipe sections in the area could be MEDICAL. A housing area of identical barracks built in 1958 could use a Pipe ID like 58 BARRACKS. If a base is divided into areas for different service groups, names such as 3RD CAV, 2ND BATT, or 9TH ARMRD might be used. Other designations, such as ADMIN, MTR POOL, AIRFIELD, or COMMISSARY are all area names that will be recognized by base personnel. (Another way to specify Pipe ID's is by street names.)

The second step in defining pipe sections is to refer to contractor installation drawings to define discrete pipe sections. A pipe section must meet the following criteria: (1) the pipe must be of a single diameter, (2) the same materials of construction must be used throughout the section, (3) the pipe must be of the same type or schedule, with the same wall thickness, (4) the soil characteristics must be the same throughout the length of the section, (5) the section length must be less than 1000 ft, (6) the sections should stop at tees and crosses, (7) any valves, pressure regulators or other appurtenances should end a section, with a new section starting on the other side of the appurtenance. The entire section must have been installed on the same date. The section ID number has four characters available (up to 9999 sections per Pipe ID), so do not hesitate to divide the piping system into as many sections as necessary. Each pipe section has a separate record in the MicroGPIPER database. The data from each pipe section is stored and retrieved using both the Pipe ID and Section ID. A Pipe Section Data Sheet (Figure 1) should be started for all sections at this point. Table 1 lists the data that is entered in the pipe section database.

The third step is to prepare a Valve Data Sheet (Figure 2) for all valves associated with each pipe section. A Valve ID can contain up to 10 characters. The easiest way to create a Valve ID is to number valves on a section sequentially (the first valve as 1, the second 2, etc.). This does not make full use of the ID field size but makes numbering on the maps easier. Other schemes could be to use the first two letters of the Pipe ID and Section ID plus a number. For example, the first valve on MEDICAL 0001 could be ME01-01. Table 2 lists the data entered in the valve database.

The fourth step is to prepare a Repair Data Sheet (Figure 3) for all repairs on a pipe section. Each ID is associated with a date of repair and the repair number. The data is self explanatory. Table 3 lists the data that is entered in the repair database.

Select Soil Sampling Sites

After pipe sections are selected, sampling sites must be chosen. Sampling locations are chosen along individual pipes in each system. It may be impractical to sample soil conditions for every pipe section during the initial survey. Data from samples taken at specific locations may be used to represent the condition of several adjacent sections of pipe. Be sure to indicate in the Comment field if soil data is not derived from a specific sample taken for that particular pipe section. It is important to select pipe sections so the soil conditions of the pipe remain the same along the entire section. Data input fields in the program only allow for a maximum of 999 ft for any pipe section. Soil conditions along a pipeline change frequently, due to geological, topographical and man-caused factors. When selecting pipe sections, long sections should be broken down into shorter lengths to ensure the accuracy of soil data. Sample locations should be chosen and marked on a map of the piping system. Maps showing the geology of the area will be useful if available.

After choosing the sampling locations, the implementor should travel to each location to ensure that sampling is feasible. Because piping system maps are generally not specific about terrain characteristics, or may be outdated, several of the sites chosen might not be usable if they are on a steep hillside, under a building, or in some other location that precludes their use. Prior to visiting each location, representatives of utilities that may have buried phone, water, or other lines at the sampling location

UNDERGROUND GAS PIPE DATA SHEET

Pipe ID: _ _ _ _ _ _ _ _ _ _ _   Section ID: _ _ _ _

Pipe Use: ☐ Natural Gas ☐ ______

Pipe Length: ______

Location From: ______

Location To: ______

Pipe Material: ☐ Black Steel ☐ ______

Coating Material: ☐ None ☐ Tape/Tar

Type of Joints: ______

Installation Name: ______

Date Installed: ______

Date Rehabilitated: ______

Date of First Leak: ______

Type of First Leak: ______

Bldg. Category: ______

Outside Diameter(In.): ______

Wall Thickness(In.): ______

Operating Pressure(PSI): ______

Depth of Burial: ______

pH of Soil: ______

Chlorides(ppm): ______

Sulfides(ppm): ______

Resistivity of Soil(ohms-cm): ______

Moisture of Soil (%): ______

Cathodic Protection(T/F): ______

Pipe to Soil Potential: ______ millivolts

As Built Records(T/F): ______

Comment 1: ______

Comment 2: ______

Date of Comment: ______

Figure 1. Pipe Section Data Sheet.

Table 1

Information Entered in Pipe Section Data Base

Field	Description
Pipe identification	This field contains the PIPE IDENTIFICATION
Section identification	This field contains the SECTION IDENTIFICATION
Section length (ft)	The length of the Pipe Section in feet
Pipe use	A phrase descriptive of the pipe contents
From	A phrase descriptive of the location of the start of the Section
To	A phrase descriptive of the lcoation of the end of the Section
Pipe material	A word describing the Pipe Material (CI, DI, etc.)
Coating material*	Blank, "BARE", "NO", "NONE" all indicate NONE. Anything else is a coating
Type of joints	A phrase descriptive of the joint type
Installation name	Name of installation
Date installed*	YYYY.MM.DD is the format
Date rehabilitated	YYYY.MM.DD is the format
Date of first leak*	YYYY.MM.DD (blank if no leak)
Type of first leak	A phrase descriptive of the type of leak
Location first leak	A phrase descriptive of the location of the leak
Building category	Military Building Category (pop-up help on screen)
Mission priority*	Military Mission Priority (pop-up help on screen)
Outside diameter	Outside Diameter in inches
Wall thickness*	Wall thickness in inches
Operating pressure*	Operating pressure in PSI
Depth of burial	Depth of burial in feet
pH of soil*	pH in the range 0 thru 14
Chlorides of soil	Soil chloride concentration in mg/kg
Sulfides of soil*	Soil sulfide concentration mg/kg
Resistivity of soil*	Soil resistivity in ohm-centimeters
Moisture of soil*	Soil moisture in percentage
Cathodic protection*	T if pipe is cathodically protected; F if it is not
Pipe-to-soil potential*	Measured potential at the test station
As-built records	T/F to indicate if as-built records exist
Comment1	A special comment by the user about this pipe section
Comment2	Indicate anything special about the pipe section
Date of comment	YYYY.MM.DD is the format

*Required field

UNDERGROUND GAS PIPE REPAIR DATA SHEET

Pipe ID: ___________ Section ID: ____

Repair Date: ____.__.__
YYYY.MM.DD

Repair ID: __

Cost: $____.__

Type: ________________

Location: ________________

Figure 2. Repair Data Sheet.

Table 2

Information Entered in Valve Data Base

Field	Description
Pipe identification	(Same as Pipe Section Database, not entered on Valve screen)
Section identification	(Same as Pipe Section Database, not entered on Valve screen)
Valve ID	Identification of the valve (10 characters)
Type	Type of valve (10 characters)
Location	Location of valve (15 characters)

should be contacted. The utility representatives can determine if any buried lines are in the vicinity of the sample sites. If any of the sample sites must be rejected, alternative sample sites can be chosen nearby. The affected Pipe Section Data Sheet (Figure 1) can be partially completed at this time. Selection of sample sites should minimize disturbance of local landscaping. Sample sites should not be located in paved areas, due to the cost of restoration after sampling. Sample sites on the edge of major thoroughfares may disrupt traffic and should be avoided. The excavation contractor should provide needed warning signs, traffic cones, and high visibility safety clothing. The initial survey will identify any special conditions requiring planning.

UNDERGROUND GAS PIPE VALVE DATA SHEET

Pipe ID: ___________ Section ID: ____

Valve ID: ___________

Type: ___________

Location: ________________

Figure 3. Valve Data Sheet.

Table 3

Information Entered Into Repair Database

Field	Description
Pipe identification	(Same as Pipe Section Database, not entered on Repair screen)
Section identification	(Same as Pipe Section Database, not entered on Repair screen)
Repair date	Date that the repair was made
Repair ID	Identification of repair made on repair date (number from 0 to 99)
Cost	Cost of repair in dollars (0 to $9999.99)
Type	Type of repair (brief description)
Location	Location (brief description)

4 FIELD DATA-GATHERING AND DATA ENTRY PROCEDURES

Inspection Reports

When the field sampling commences, the project manager should keep a record of daily activities. The daily log should list all persons present, weather conditions, work performed, and any observations pertinent to the procedure. Daily logs may be combined into an Inspection Report covering all the field activities. A useful Daily Inspection Report Form is included in Appendix A.

Sample Collecting

Excavation activity should commence with the intention of returning the sample area to its original condition. Sod may be cut and rolled for ease of replacement. Tarps may be used to stockpile the excavated soil during sampling. This will speed cleanup and restoration of the sample site. During the sample collection procedures, soil excavation should proceed slowly to prevent damage to the pipe caused by the backhoe. As soon as the pipe is located, further excavation should be performed using hand tools until approximately 1 ft of the pipe is exposed.

After each section of pipe has been exposed, it should be thoroughly inspected for damage caused during soil excavation. Information about the pipe should be recorded. A Pipe Section Data Sheet is used for recording information because it provides a complete list of the data to be collected. A blank Pipe Section Data Sheet is shown in Figure 1.

Soil should be sampled as close to the surface of the pipe as possible to provide a representative sample of the soil that is in contact with the pipe. The following equipment is necessary for soil sampling:

- 32 oz (1 L) sample jars
- sampling scoop(s)
- latex gloves
- deionized water.

It is important to prevent moisture from being evaporated from the soil sample. After a representative sample is collected and placed into the sample jar, the jar should be tightly capped, labeled, and packed in blue chemical ice in a cooler for later delivery to the lab. If a reusable sample scoop is used, it must be thoroughly washed with deionized water and dried with a clean paper towel between samples.

Examine a 1-ft section of pipe. Note the condition of the pipe coating. If there is no coating or if the coating is damaged, measure the average corrosion pit depth of the section using a pit depth gauge, and use this information to compare predicted vs. actual CSI. The accuracy of the prediction model for a particular installation can be determined from the actual CSI obtained at sampling locations. (See Chapter 2 for model accuracy.)

After the sampling and testing is complete, the pipe should be covered with select fill material. Take care to provide proper bedding and backfill, and to exclude large rocks and debris to prevent premature mechanical damage to the pipe section. If sampling activities require removal and replacement of asphalt or concrete paving, the backfill must be compacted to 95 percent Proctor density prior to patching the surface. DEH personnel should insist on complete restoration of the excavation area by the contractor.

Sample Identification and Shipment

Prior to shipping samples to the selected laboratory for analysis, they must be properly labeled and packaged for shipment. The label should include at least the following information:

- pipe ID number and section ID numbers
- name of source or location
- date and time
- name of sample collector
- sample identification number.

The samples should be placed in a shipping container (if it is necessary to ship them) and packed with blue ice and appropriate packing material to avoid breakage. A laboratory analysis request sheet, a chain of custody report and instructions for sample disposition should accompany the sample to the laboratory.

Data Entry and Maintaining the Database

Once the data described in the preceding section has been collected, it may be put into MicroGPIPER. See the MicroGPIPER User's Manual for specific instructions on the operation of the program. After data entry is complete, reports may be generated. A description of the reports and their suggested uses are given in Chapter 5 of this guide.

To ensure maximum usefulness of MicroGPIPER, the database should be updated as repairs are made and as more data about the piping system and surrounding soil becomes available. Accurate records save time and facilitate maintenance decisions. Information on leaks and repairs should be input as they occur. This allows maintenance personnel to observe trends over time and to locate and track particular trouble spots. The pipe section database should be updated if modifications (such as replacement or addition of pipe) are made to the gas piping system.

The following are three different data files located in the database under each pipe section ID:

- PIPE/SOIL/LEAK data
- VALVE data
- REPAIR data.

Pipe sections without specific soil samples taken during the initial implementation may have their soil data updated during repair or maintenance activities. A leak or break requiring repair will provide an opportunity to take soil samples and perform pit depth measurements so that the actual and predicted CSI's can be compared. to check the inventory of valves in the section. After repairs are finished, the data should be entered into the REPAIR data file. Soil sample data may be entered when laboratory results are received, updating the PIPE/SOIL/LEAK data.

Two forms have been developed to assist maintenance personnel in gathering complete data during the course of normal repairs. When a pipe section is repaired, the Repair Record Form (Figure 4) should be used to document the repair for later data entry. The first section of the form contains the information needed for the MicroGPIPER database. The comment section provides room for additional details that are not needed for long term management of the piping system. Should no soil sample exist for the section being repaired, a soil sample may be collected and the Soil Sampling Record Sheet (Figure 5) completed. It should be standard procedure to collect a soil sample any time an underground pipe is uncovered for maintenance. Samples duplicating previous tests need not be sent in for laboratory analysis.

It should also be standard procedure to perform pit depth measurements when a pipe is uncovered for maintenance. This should be used to verify the accuracy of the CSI predictions for the installation. The pit depth measuring procedure and information on model accuracy is contained in Chapter 2.

UNDERGROUND GAS PIPING REPAIR RECORD

DATA ENTRY GPIPER

Pipe ID: ___________ Section ID: _____

Date of Repair: ____________________

Repair No.: ____________________

Est. Cost of Repair: ____________________

Type of Repair: ____________________

Location of Repair: ____________________

ADDITIONAL COMMENTS

Description of Problem: ____________________

____

____

Sketch of Repairs Made:

Exterior Corrosion? Y N
Interior Corrosion? Y N
Heavy Traffic Area? Y N
Construction in Area? Y N
Soil Saturated? Y N
Soil Sample Taken? Y N

(Attach Sample Record Sheet)

Figure 4. Repair Record Sheet.

UNDERGROUND GAS PIPE SOIL SAMPLING RECORD

Pipe ID:___________ Section ID:____

Pipe Use: ☐ Natural Gas ☐ ________

Pipe Length: ____________________

Location From: ____________________

Location To: ____________________

Sample Location Description: ____________________

____

Depth of Burial: ____________________

Pipe Material: ☐ Black Steel ☐ ________

Coating Material: ☐ None ☐ Tape/Tar

Type of Joints: ____________________

Outside Diameter(in.): ____________________

Cathodic Protection: Y N

Pipe to Soil Potential: ____________________ millivolts

Weather Conditions: ____________________

Samples Taken By: ____________________

Sample ID: ____________________

Laboratory Sent To: ____________________

Date Sent: ____________________

Results: pH ______ % Moisture ______

Chlorides ______ Resistivity ______

Sulfides ______

Figure 5. Soil Sample Data Sheet.

5 DATA EVALUATION PROCEDURES

Database Query and Sort Order

Once a database has been entered, the information can be used in many ways. MicroGPIPER is already programmed to generate the most frequently needed reports. You need only select the desired report from the Database Related Reports Menu, and then specify where the report is to be printed. In addition to the program-generated reports, you may create and print out customized reports. This ability is covered in detail in Chapter 4 of the *MicroGPIPER User's Manual.* This chapter includes a brief description of each report and how the reports can be used to develop an overall maintenance strategy. You may specify which pipe sections to include in the Data Specifications report and the Summary report, and may arrange them in various orders. This is accomplished by setting the Report Query. A query is a condition that a pipe section must meet to be used in this report. The query limits the number or sections that are included in the reports. Up to five queries may be input for a report. MicroGPIPER has three forms that a query may take: list, relational, or range.

The list query allows you to enter a list of values that a data field must match to be included in a report. For instance, a list of pipe diameters could be entered. All pipe sections whose diameter was not on the list would be excluded from the report. A list may contain up to eight values.

The range query requires that the data in a field fall within a specified range in order to be included in a report. For instance, a query could require that a pipe section be installed between two dates to be included in a report. You may set a range so narrow that few—or no—pipe sections will qualify. Take care to use realistic numbers.

The relational query requires that data in a field be larger, smaller, or equal to a given value. You select a relation (less than, less than or equal to, greater than, greater than or equal to) and input a value. For instance, a query could require that the numbers of repairs must be larger than or equal to three for a pipe section to be included in a report. All records of pipe sections with fewer than three repairs reported would be dropped from the report.

Following the set query section, MicroGPIPER requests the Sort Order. This allows you to select the order in which the pipe sections in the Summary Report print. In the Data Specification Report, any Sort Order set in the Query section is overridden by the Sort Order set in the Data Specification Report. You may sort the pipe sections in ascending or descending order for each sort order specified.

The query conditions will limit the number of pipe sections included in only the Data Specification Report and the Summary Report. The other reports will continue to use the entire database and include all pipe sections.

Data Specification Report

The data specification report allows you to print out chosen information (data fields) from the pipe section database. The data fields will be printed out in columnar format for each of the pipe sections that meet the criteria specified in the Query section. You can set the order in which the columns will appear across the page. This allows you to print only the needed information, and to arrange it in a logical manner. You can also set the order in which the pipe sections will be displayed. This allows you to organize the data as needed for various tasks. For example, you might wish to get a listing of pipe sections arranged according to their installation date. The data fields to be printed and the order in which they are printed may be easily changed. The options are only limited by printer output restraints.

The Specification Report can be used to generate support data for budget requests. The report allows the presentation of the data in a logical order, leading to a clear conclusion.

Summary Report

Selection of the Summary Report results in the automatic generation of a report that lists the use and location of all pipe sections in the database that meet any conditions set in the Database Query and Sort Order. The Summary Report helps to quickly determine the number of records that meet the query conditions set. The order in which the pipe sections are arranged follows any sort order set previously in the Database Query and Sort section. If no sort order has been set, the data will be arranged by ID number, in ascending order.

Corrosion Status Index Prediction Report

This report allows you to review the actual and predicted corrosion status of individual pipes.

The Corrosion Status Index (CSI) is a measure of the relative condition of a pipe. (Its calculation is described in Chapter 2.) The CSI can range from 100 for a new pipe to zero for a completely deteriorated pipe. As stated earlier, the first leak occurs when the CSI = 30.

The CSI Prediction Report calculates the predicted first leak for each pipe section. To further assist in planning, the report lists the projected number of leaks per mile of pipe for each year after the first leak has occurred. If the actual date of the first leak is entered, the formula is adjusted and a second corrosion curve is printed on the report. This gives a graphic representation of the calculated and actual corrosion status index vs time for the entire life of the pipe. The CSI Report for each pipe section includes tabular data also. The CSI values generated in this report should be compared with actual measurements of the pit depth taken during the field survey to determine the accuracy of the prediction model for the installation.

Condition Frequency Report

The overall condition of the pipes in the database is presented as a histogram in this report. Each pipe section in the database is assigned a condition class, from "excellent" to "failed." The number of pipe sections in each condition class is totalled, and presented in the histogram. The percentage in each condition is also printed. This Condition Frequency Report may be used in reports and presentations to quickly show the overall condition of a pipe system. The pipe sections are placed in a condition class according to the following criteria:

- CSI of 0 to 19 = Failed
- CSI of 20 to 29 = Very Poor
- CSI of 30 to 39 = Poor
- CSI of 40 to 59 = Fair
- CSI of 60 to 69 = Good
- CSI of 70 to 80 = Very Good
- CSI of over 80 = Excellent

Any records with data insufficient to calculate CSI are dropped from the report.

Priority Ranking Report

Budgeting for maintenance and improvement costs requires that high maintenance areas be considered first. MicroGPIPER can help predict the leak rate and maintenance requirements for each pipe section. The Priority Ranking Report lists the pipe sections in the selected database by urgency for repair. The ranking considers the CSI and the gas pressure to rank the pipe sections from most in need of repair at the top, to least in need of repair at the bottom. This report alerts the maintenance manager to trouble spots where increased repair costs are expected. The report shows the ranking in the left hand column and lists the values for CSI, pressure, and mission priority. If the rank of two different pipe sections is equal, the report lists the sections by ID number in ascending order.

Valve Report

This report provides a list of all valves in the system. The Valve Report is a convenient source of information when a repair is needed or when estimating rehabilitation costs. This information is also useful when performing routine maintenance such as valve exercising and lubrication. Records of valve type, size, and pressure settings for regulating valves may be kept. The Valve Report prints all records of valves included in the database.

Repair Report

This report lists all repairs performed on the system. The Data Entry program allows a record to be kept of all repairs performed on a pipe section. The information stored includes:

- date of repair
- ID number of repair
- cost of repair
- type of repair
- repair location.

The Repair Report lists all repairs in the database, arranging the records by Pipe Section ID Number and Repair ID Number. The Repair Report is a convenient way to track maintenance costs and to assist in planning future rehabilitation projects. The report is automatically formatted and printed, so access to the repair information is rapid.

Bad Record Report

This report lists records containing bad or incomplete data. Bad data is rare, but may occur if data is manipulated externally from MicroGPIPER with dBase.

When you enter data, MicroGPIPER interactively assists you with pop-up menus and prompts. Generally it is difficult to enter the data incorrectly, since MicroGPIPER is programmed to question unreasonable values. If you attempt a blank entry, the cursor stays on a datafield and forces a correction before continuing. The Bad Record Report should be checked after entering new data, prior to printing out other reports.

Cost Analysis Program

This program feature allows you to do simple life cycle cost analysis of repair or replacement alternatives.

The costs associated with maintenance of an underground pipe system vary for each installation since rehabilitation and replacement costs depend on local labor and material costs. Once accurate costs are assembled, the various alternatives must be compared in an understandable form that allows an easy choice between diverse alternatives.

The ECON-1 Advanced Economic Analysis program uses two comparison methods to evaluate alternatives. First, the program reduces all costs throughout the study period to their present worth values. The present worth calculation takes into account the expected interest and inflation rate, and converts future expenditures into current dollars. The various costs are combined into a single present value figure that shows the least expensive alternative. Next, MicroGPIPER calculates the Equivalent Uniform Annual Cost (EUAC), the annual amount spent during the life of the alternative, where the total present value equals the present value of the alternative. This figure is useful for planning and preparation of multiyear budgets. The EUAC is also calculated on a per-foot-of-pipe basis. The EUAC helps compare maintenance and repair alternatives.

One common situation is a deteriorating pipeline with escalating repair costs. Any decision between repairing and replacing the pipeline must consider the costs of continued maintenance vs. replacement costs. The costs analysis example in Appendix B shows the economics of delaying a pipe section repair assuming that the pipe section has begun to leak and requires repairs. Repairs will increase in frequency as the pipe continues to deteriorate. In the example, pipe replacement may be delayed up to 2 years with little impact on economics, after which further delay will result in rapid escalation of maintenance costs (and is economically unsound).

6 SUMMARY

MicroGPIPER provides a system that uses soil or pipe parameters to predict and prioritize corrosion status and long-range planning for maintenance of underground gas piping. MicroGPIPER generates reports that show the current status of piping systems, and project future conditions. The program includes an electronic inventory system to record historical pipe data, to maintain a repository for maintenance records, and to provide an economic analysis package for underground gas-piping networks. The economic analysis package can help Army facility managers evaluate the economic feasibility of maintenance and rehabilitation management strategies. The accurate predictions of future costs calculated by MicroGPIPER can enhance budget justification. Its user-friendly features allow new users to quickly master the data entry and report generation features. Once installed, MicroGPIPER has low labor requirements for updating the database.

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APPENDIX A: SAMPLE IMPLEMENTATION SPECIFICATION FOR GPIPER

OVERVIEW

This Appendix contains an example of a scope of work that may be used by an Army installation wishing to utilize a contractor for the implementation of GPIPER. Words that are in **[bold print and brackets]** indicate site specific data that is to be inserted by the installation. This Appendix is only intended to be a guide for the technical content of the scope of work. Each installation may wish to add, change, or delete sections or use a different format depending upon its typical contracting procedures.

Maps are referred to throughout the specification. These maps are to be supplied by each installation as an attachment and are not included in this publication.

The remainder of Appendix A contains the complete sample implementation specification. At the end of Appendix A is a sample daily inspection report (as referenced in Chapter 4) which may be used during the field data collection procedure.

SCOPE OF WORK

IMPLEMENTATION OF GPIPER
AT
[INSTALLATION'S NAME]

1.0 GENERAL

1.1 APPLICABLE PUBLICATIONS: The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

1.1.1 U.S. Army Construction Engineering Research Laboratories (USACERL)

USACERL Technical Report	*MicroGPIPER Implementation Guide*
USACERL ADP Report	*MicroGPIPER Users Manual*

1.2 SYNOPSIS OF WORK

The Contractor shall furnish all materials and perform all services required to implement the GPIPER computer program as set forth in these detailed specifications for **[installation's name]**. Approximately **[insert number]** linear feet of underground piping are to be included. Maps showing the appropriate pipes are given in Appendix III of this specification. GPIPER is a maintenance management system that stores data on underground gas-piping systems and the surrounding soil, and assists in prioritizing sections of the system for repair and rehabilitation based upon corrosion rate and leak predictions. Work shall be accomplished in accordance with the publications cited in section 1.1, except as modified elsewhere in these specifications. The following items of work, explained more fully in Sections 2.0 through 6.0, are included:

1.2.1 Inventory and Initial Field Data Collection: Establish an identification system for the specified underground pipes, as directed in the MicroGPIPER Implementation Guide. Furnish reproducible mylar maps showing the pipe network and valves with all of the identification numbers clearly marked. Collect and record all of the required data for each pipe section as explained under Section 2.0, INVENTORY AND INITIAL FILED DATA COLLECTION.

1.2.2 Data Entry: Enter all data into the GPIPER program and provide a complete database and an error-free run.

1.2.3 Generation of Reports: Furnish computer printouts of the reports specified in Section 4.0. These reports show the information input into the data base, and provide leak predictions and prioritizations for each pipe section. Include these in the final report, along with a discussion of the results. Provide recommendations where applicable.

1.2.4 Training: Provide training to DEH personnel on the GPIPER system setup and use.

1.2.5 Preparation of Final Report: A final report as discussed in Section 6.0 shall be prepared with a formal narrative section describing the work and method of accomplishment. All data and program-generated reports shall also be included. The final report shall be presented to the DEH at an exit briefing.

1.3 PROJECT MANAGEMENT

1.3.1 Project Supervisor: The supervisor shall serve as a single point of contact and liaison for all work required under this Contract. Upon award of the Contract, this individual and an alternate shall be immediately designated in writing by the Contractor. These designated individuals shall be approved by the Government Project Engineer. One of these individuals shall be available at the installation whenever the Contractor is performing work under this Contract.

1.3.2 Installation Assistance: A duly authorized representative from within the Directorate of Engineering and Housing will serve as the point of contact for obtaining available information and assisting in establishing contacts with the proper individuals and organizations, as necessary, in the accomplishment of the work required under this Contract.

1.3.3 Public Disclosures: The Contractor shall make no public announcements or disclosures relative to information contained or developed in this Contract, except as authorized by the Contracting Office.

1.3.4 Conferences: Conferences shall be scheduled as shown on the Implementation Schedule based on work status or whenever requested by the Contractor or Government Project Engineer for the resolution of questions or problems encountered in the performance of the work. The Contractor shall be required to attend and participate in all conferences pertinent to the work as directed by the Contracting Officer.

1.3.5 Qualifications of Personnel: Field inspections and data collection shall be performed by technically trained personnel under the direct supervision of a registered professional engineer experienced in evaluating underground gas piping. All data shall be, at a minimum, reviewed and signed by a registered professional engineer experienced and qualified in underground gas pipe network maintenance and rehabilitation.

1.3.6 Scheduling: At the beginning of the contract period, the Contractor shall submit an implementation schedule using the format shown in Appendix II of this specification for approval by the Government Project Engineer. Detailed schedules for field work will be coordinated through the Government Project Engineer each week. In-progress reviews should be scheduled as follows:

- At the completion of establishing the segmented network in the office and prior to proceeding with any field work
- At the completion of the field survey data input
- At the final exit briefing during the presentation to the DEH of the complete GPIPER system.

Incremental Contractor-checked data shall be furnished to the government as required by the Government Project Engineer for review and concurrence.

1.4 PAYMENT

1.4.1 Overhead, Supervision, Site Visits and Inspection: All overhead, supervision, travel costs, and other expenses to be incurred by the Contractor, directly or indirectly, including costs of the site visits throughout the work, shall be included in the proposal under the work items described. These costs shall not be considered separately.

1.4.2 Monthly Payment, Less Deductions: The Contractor shall be paid, upon the submission of proper invoices or vouchers, the prices stipulated in the proposed schedule rendered and accepted, less deductions, if any, as herein provided. Unless otherwise specified, payment will be on performance accepted by the U.S. Government when the amount due on such performance so warrants. Payment may be requested not more than once each month.

1.4.3 10 Percent Retention: In making such payments, the U.S. Government may, at its option, retain 10 percent of the estimated amount until final completion and acceptance of the Contract work. However, if the U.S. Government, at any time after 50 percent of the work has been completed, finds that satisfactory work is being performed, it may authorize any of the remaining payments to be made in full. When the work is substantially complete, if the Government considers the amount to be retained in excess of the amount adequate for the protection of the U.S. Government, the Government may, at its discretion, release to the Contractor all or a portion of such excess amount.

1.4.4 Final Payment on Release: Upon completion and acceptance of all work, the amount due the Contractor under this Contract is dependent upon the presentation of a properly executed voucher after the Contractor has furnished the U.S. Government with a release, if required, of all claims against the U.S. Government arising by virtue of this Contract, other than claims in stated amounts as may be specifically expected by the Contractor from the operation of the release. If the Contractor's claim to amounts payable under this Contract has been assigned under the Assignment of Claims Act of 1940, as amended (31 U.S.C. 203, 41 U.S.C. 15), a release may also be required of the assignee.

1.5 SAFETY

The Contractor shall conduct operations in a safe manner at all times. Safety provisions shall be consistent with the Army Corps of Engineers Safety Manual. The Contractor's operation shall not cause a potential safety hazard to occupants of the area, Contractor's and U.S. Government personnel, and U.S. Government property.

1.6 CONTRACTOR & INSTALLATION WORK HOURS

The normal hours of operation at the installation will be between **[insert hours]** Monday through Friday except on the following Federal holidays:

New Years Day	President's Day	Thanksgiving
Memorial Day	4th of July	Martin Luther King Day
Labor Day	Veterans Day	Columbus Day

Field work in Family Housing areas shall be conducted during the hours of **[insert hours]**. Other site conditions or security requirements may necessitate that the required field work be performed outside of the normal hours of operation.

1.7 ACCESS TO RESTRICTED AREAS

The list of pipe sections which are in restricted areas, and the procedure to obtain access to these areas is as follows: **[insert list of pipe sections and access procedures]**

1.8 CONTRACT DURATION

The Contract completion date shall be **[insert number]** calendar days after the Notice to Proceed has been received by the Contractor.

1.9 POINTS OF CONTACT

1.9.1 Directorate of Engineering and Housing Point of Contact: **[list name(s) here]**

[INSERT OTHER ORGANIZATIONS AND POINTS OF CONTACT HERE AS APPLICABLE]

2.0 INVENTORY AND INITIAL FIELD DATA COLLECTION

2.1 GENERAL

A complete description of the inventory and data collection requirements for GPIPER is given in the USACERL Technical Report *MicroGPIPER Implementation Guide*. The Contractor shall utilize installation drawings and records, perform field surveys, conduct interviews with DEH personnel, and assemble other information as necessary to gather the required data. The Contractor shall make a reasonable effort to obtain 100 percent of the required data. If any part of the required data cannot be collected, the Contractor shall submit in writing a complete list of the unavailable data, along with a reason for its unavailability. The reason must be approved by the Contracting Officer before the database will be accepted as "error-free" as discussed in Section 3.0. A complete listing and explanation of unavailable data shall also be given in the final report. The Contractor shall copy blank forms from the MicroGPIPER Implementation Guide or other reference as necessary to perform work and submit with the final report as specified by this Contract.

2.2 DEFINITION AND IDENTIFICATION OF PIPE SECTIONS

The Contractor shall define and set up an identification system for the underground gas distribution piping covered under this Contract. This procedure involves dividing the system up into a series of pipe sections, each with its own identification number. In addition, all valves are given an identification number. The identification numbers selected shall be approved by the Directorate of Engineering and Housing. When selection of identification numbers is made, the appropriate facilities and suffix numbers of the installations Integrated Facilities System (IFS) should be checked to determine compatibility. The pipe sections and valves shall be clearly identified on the reproducible maps described in 1.2.1.

2.3 COLLECTION AND VERIFICATION OF PIPE SECTION DATA

The Contractor shall collect a complete set of data as described in the GPIPER Implementation Guide for each pipe section identified under paragraph 2.2. This information shall be collected on the Pipe Section Data Sheet provided in the GPIPER Implementation Guide or a reasonable facsimile thereof. One form shall be completed for each pipe section. It is the Contractor's responsibility to reproduce the forms in sufficient quantities to collect data for the entire system. The following information is required for each pipe section:

- pipe ID
- section ID
- location from
- location to
- length (ft)
- pipe material
- coating material
- type of joints
- date installed
- date rehabilitated
- date & type of first leak
- outside diameter (in)
- wall thickness (in)
- operating pressure (PSI)
- depth of burial
- pH of soil
- chlorides of soil
- sulfides of soil
- resistivity of soil (ohm-cm)
- moisture of soil (%)
- Is pipe cathodically protected?
- pipe to soil potential.

The contractor shall verify that all pipes shown on the maps actually exist, and verify information including pipe diameter and length (as much as practicable). Soil sampling and analysis and pit depth analysis shall be conducted in accordance with the procedures given in paragraph 2.4 below. Pressure data shall be collected in accordance with paragraph 2.5. Leak history data shall be collected in accordance with paragraph 2.6.

2.4 SOIL ANALYSIS AND PIT DEPTH ANALYSIS

2.4.1 General: Locations of soil sampling and pit depth analysis excavations shall be determined through coordination with Directorate of Engineering and Housing personnel. There shall be a *minimum* of one excavation per mile of pipe. Care shall be taken to position the excavations so as not to disturb nearby structures and landscaping. Sod shall be cut and rolled for restoration of site. Contractor shall provide a backhoe suitable for excavations to at least 6-ft depth. Crews shall be equipped with shovels and other implements for hand excavation around the pipe. A pipe locating device shall be used. Care shall be taken when nearing the level of the gas piping to prevent damage to the pipe and coating. All of the soil analysis and pit depth inspections will be performed using visual means, hand tools, and laboratory soil analysis techniques as appropriate. After a section of pipe has been exposed for pit depth measurement and soil data collection, it should be thoroughly inspected for damage caused during excavation. Any pipe or coating damage shall be repaired. Pipe repair tape/wrap shall be compatible with the existing coating. No exposed steel will be allowed, and repair shall meet with the Government Project Engineer's approval prior to recovering the pipe. After sampling is complete, the pipe shall be covered with appropriate fill material and the excavation site shall be restored as nearly as practicable to its original condition. Sod replacement shall follow standard horticultural procedures. All debris and unsuitable backfill material shall be removed from the site. The above number of excavations are for cost-estimating purposes only.

2.4.2 Soil Sample Collection: Approximately **[insert number]** soil samples will be collected. Samples are to be representative of the soils in contact with the buried gas pipeline and shall be taken immediately upon exposure of the pipe. Samples shall not be taken during precipitation. Samples shall be collected in new polyethylene sample containers with 32 ounce capacity. A clean plastic scoop shall be used to fill the sample container. Reusable scoops shall be cleaned and rinsed with deionized water between sampling events and dried thoroughly. The containers shall be securely closed and placed in a cooler. Blue chemical ice will be used to chill the samples during storage and shipment to minimize moisture loss.

2.4.3 Soil Sample Analysis: Soil sample analysis shall be performed by a U.S. Environmental Protection Agency (EPA) certified laboratory. The following quantities shall be determined for each sample:

- pH
- resistivity (ohm-cm)
- sulfide content (ppm)
- moisture content (%)
- chloride content (ppm).

2.4.4 Pit Depth Measurement: At each excavation site, the Contractor shall use a pit depth gage to measure the average and maximum pit depths for a 1-ft long section of pipe. These measurements shall be recorded on the data sheets. The Contractor shall also note and record the condition of the pipe coating.

2.5 PRESSURE SURVEY

The contractor shall measure the gas line pressure at appropriate locations as determined through coordination with DEH personnel. Pressures shall be recorded on the pipe section data sheets.

2.6 LEAK HISTORY

Existing records will be reviewed to determine all past leaks repaired on each pipe section. Interviews may also be conducted with Directorate of Engineering and Housing personnel.

3.0 DATA ENTRY

3.1 GENERAL

The Contractor shall code for entry into GPIPER all verified data collected in sections 2.3 through 2.6 above from installation drawings and records, field surveys, interviews, or other sources. Coding for the computer shall be in accordance with the GPIPER User's Manual. The result shall be a complete, error-free database.

3.2 DATA ENTRY

The Contractor shall enter data into the data base on a Government-owned microcomputer. The Government shall provide a copy of the GPIPER program for the Contractor's use. The Contractor shall ensure and verify that the data stored in the database corresponds with the field data. Care shall be taken to ensure that data input into the database follows a sequence that avoids duplication or omissions and provides as a finished product an error free, complete database ready for GPIPER maintenance management operations.

3.3 INITIAL DATA CHECKING

The structure and test site identification information shall be entered, checked, corrected by the Contractor, and approved by the Government's Contracting Representative prior to other data being input into the program. This information must correspond to the reproducible drawings covered in Paragraph 1.2.1.

3.4 DATA CHECKING

When the structure and test site information is approved and the remainder of the data has been entered, checked, and corrected by the Contractor, the Contractor shall produce one copy of the data stored in the computer for review by the Government. Any input errors discovered through the review of this "data dump" will be changed by the Contractor within a 2-week period after the review.

3.5 FINAL DATA CHECKING

If 5 percent or more of the data requires changes, a second "data dump" and review will be required. The Contractor will respond to changes of the second data dump within a 1-week period. Review and correction will continue in this same fashion until the data base is error free.

4.0 GENERATION AND INTERPRETATION OF REPORTS

The Contractor shall generate the following reports from the final, error-free GPIPER database:

- Corrosion Status Index (CSI) Prediction Report for each pipe section
- Frequency Report
- Priority Ranking Report
- Summary Report
- Repair Report.

Based upon these reports and upon observations made during the field survey, the Contractor shall identify locations in the gas-piping system where repairs or further investigations are warranted. The Contractor shall provide recommendations as to the nature, extent, and "ballpark" cost of these activities.

In addition, the Contractor shall compare the predicted pit depths, CSIs, and number of leaks with the pit depths and number of leaks that actually exist in the field.

5.0 TRAINING

5.1 CLASSROOM INSTRUCTION

The Contractor will provide a minimum of **[insert number]** hours of training in the use of the GPIPER System to employees of the DEH during the Contract. This orientation and training will include, but is not to limited to, the following:

- computer and program start-up
- definition of pipe sections
- data collection (i.e., pipe dimensions, soil chemistry, pressure data, leak records)
- data entry and editing
- report generation
- interpretation of reports
- use of the reports to assist with M&R planning
- backing up the data base
- exiting the program.

5.2 SCHEDULING

A training schedule will be coordinated with and submitted to the DEH for approval a minimum of 15 working days prior to the training. The Contractor will contact the DEH representative directly to reserve conference rooms and training areas and to check the availability of audio/visual equipment, computer terminals, and other equipment or facilities necessary for the training. Equipment (e.g., audio/visual equipment, computer terminals, etc.) that is necessary for the training but is not available from the DEH shall be furnished by the Contractor.

5.3 LIST OF ATTENDEES

The Contractor shall include, in the final report, a list of DEH personnel including name, title, office symbol, and telephone number that were trained under this contract.

6.0 FINAL REPORT

6.1 REPORT FORMAT

Formal reports and tabular data shall be typed or computer-printed (at least near letter quality) on 8-1/2 x 11-in. bond paper with foldouts for maps, sketches, schematics, charts, graphs and other illustrative material, as may be necessary. Data which cannot be clearly described in narrative form shall be shown graphically.

6.2 REPORT BINDING

Formal documents shall be securely bound with a durable cover. The title of the document shall appear on the cover of all submittal documents. Final documents shall be bound in a manner that will facilitate repeated disassembly and reassembly, unless otherwise specified herein.

6.3 NETWORK DRAWINGS

Site maps showing the locations of each pipe section and valve shall be reproducible mylar drawings. The drawings shall provide easy identification of the pipe sections and valve.

6.4 REPORT SUBMITTAL

[Insert number] preliminary (draft) copies of the final report shall be submitted to the Government for approval. Following the return of comments, the Contracting Officer will schedule a meeting for their discussion if necessary. The Contractor shall furnish written notification of intended action on each comment within 1 week after this meeting. Intention of noncompliance with any comment shall be substantiated in detail. Authorization to proceed with final submittal will be granted in writing with or after the Contracting Officer's approval of the contractor's intended actions on the review comments. **[Insert number]** copies of the final report will be submitted.

6.5 ORGANIZATION OF REPORT

Narrative contents shall be arranged in a logical sequence and organized by sections. Reproducible transparencies, drawings, and/or maps shall be submitted separately. The report shall fully document the implementation process, the data collected, and the results achieved. The report shall include, but is not limited to, the following items:

6.5.1 A formal narrative section describing the work that was done, how it was accomplished, and when it was accomplished. The narrative shall include a brief description of each of the following portions of this report.

6.5.2 The GPIPER reports specified in Section 4 shall be generated from the completed data base and submitted as part of the final report.

6.5.3 Based upon the results of the above reports, the contractor shall note areas of the system in which further investigation is warranted to pinpoint problems or potential leaks in the gas-piping system. The contractor shall make recommendations as to the nature, extent, and approximate "ballpark" cost of these investigations.

6.5.4 A list of DEH personnel including name, title, office symbol, and telephone number that were trained by the Contractor under the Contract.

6.5.5 An Appendix containing copies of all of the data collection forms that were completed under Section 2, Inventory. These shall be arranged in an organized, logical sequence.

6.5.6 All maps and drawings necessary to identify the gas pipe sections, including two copies of the mylar maps.

6.5.7 A backup copy of the complete, error-free GPIPER database on 5-1/4 in. floppy disks.

6.6 EXIT BRIEFING

Upon completion of the work, an exit briefing will be given to the DEH. The final report shall be presented to the DEH at this briefing. The briefing shall cover the scope of work, accomplishments, findings, problems, conclusions, and identification of problem areas in the gas-piping system.

CONTRACT SPECIFICATION APPENDIX I

LIST OF GOVERNMENT FURNISHED MATERIALS AND INFORMATION

The Government shall furnish the following items at the time the Notice to Proceed is issued, however, all will be returned to the Government at the end of the project:

- area site plan maps (1 set)
- supplemental area maps (1 set)
- maps of gas distribution system (1 set) (If maps do not exist, other descriptive material shall be provided as available.)
- other existing background or historical information such as leak records (as available) that cannot be readily measured in the field by the Contractor and is required under Section 2.0, Inventory
- GPIPER computer program
- USACERL Technical Reports *MicroGPIPER Implementation Guide* and *MicroGPIPER User Manual.*

CONTRACT SPECIFICATION APPENDIX II

IMPLEMENTATION SCHEDULE

ITEM NUMBER

1. Mylar Maps . . . .

2. Pipe Section Identification . . . .

3. Background and Field Data Collection . . . .

4. Data Entry . . . .

5. Report Generation and Interpretation . . . .

6. Training . . . .

7. Final Report and Briefing . . . .

0 20 40 60 80 100 120 140 160 180 200
Calendar Days from Contractor's Notice to Proceed

[INSTALLATION MAPS SHOULD BE ATTACHED AS APPENDIX III. ANY OTHER ATTACHMENTS SUCH AS PRICE/COST SCHEDULES SHOULD BE INCLUDED IN ADDITIONAL APPENDICES]

SAMPLE DAILY INSPECTION REPORT

Daily Inspection Report No. ________

Contractor ________

Supt. on Job ________ Sheet ____ of ____

Weather ________ Date ________

________ Temperature ____ °F Max ____ °F Min Project ________

Work Hours ____ to ____ Memos Issued ____

Photos ________ Job No. ________

Special Conditions, Delays, Changes ________

Accidents Damage ________

Sampling, Testing ________

Visitors to Site ________

Work Report (Work done, Personnel/Equipment working) ________

Distribution: Inspection File (orig)
Field File

By ________

Figure A1. Sample Daily Inspection Report.

APPENDIX B: ANSWERS TO COMMON QUESTIONS AND COST ANALYSIS EXAMPLE

Answers to Common Questions

Q. Should a valve key be created for numbering valves?

A. There is no benefit in creating a new ID key for the valve records. It is best to use the valve numbering system found on the plan drawings. This will avoid confusion caused by having two ID numbers for a single item. During field surveys, look for stamped brass numbering tags attached to valve wheels or stems. The tags, used on many systems, will help you locate the valve on the plans and verify its location.

Q. How should the pipe be located in the safest manner?

A. The exploratory excavation should be run parallel to the expected direction of the pipeline. The digging motions of the backhoe parallel to the pipe may scrape it, but the chances of hooking underneath the pipe and rupturing it are greatly reduced.

Q. Can databases from MicroGPIPER be copied for use with other software?

A. No. The database format will not be compatible and no facility to translate files is included.

```
                          ECON1 REPORT
                 REPORT DATE: 1990.03.08     13:27:20

     PROJECTED COST ANALYSIS                     (DETAIL)

Section ID          :EXAMPLE FOR GUIDE

Section Length      :      500 feet
Interest Rate       :     8.00 %     Inflation Rate     :     6.00 %

Alternative         : REPLACE PIPE NOW
Life of Alternative : 25
M&R ACTIVITY                  YEAR     COST($)      PRESENT VALUE($)

REPLACE PIPE                  1990    53900.00              53900.00
                            Total:    53900.00              53900.00

Initial Cost ($)                         :       53900.00
Present Value ($)                        :       53900.00
Equivalent Uniform Annual Cost (EUAC)    :        5049.29
EUAC per Linear Foot                     :          10.10
```

ECON1 REPORT
REPORT DATE: 1990.03.08 13:32:20

PROJECTED COST ANALYSIS (DETAIL)

Section ID :EXAMPLE FOR GUIDE

Section Length : 500 feet
Interest Rate : 8.00 % Inflation Rate : 6.00 %

Alternative : REPLACE PIPE NEXT YEAR
Life of Alternative : 25

M&R ACTIVITY	YEAR	COST($)	PRESENT VALUE($)
REPAIR	1990	800.00	800.00
	Total:	800.00	800.00
REPLACE PIPE	1991	53900.00	52901.85
	Total:	53900.00	52901.85

Initial Cost ($) :	800.00
Present Value ($) :	53701.85
Equivalent Uniform Annual Cost (EUAC) :	5030.72
EUAC per Linear Foot :	10.06

ECON1 REPORT
REPORT DATE: 1990.03.08 13:36:30

PROJECTED COST ANALYSIS (DETAIL)

Section ID :EXAMPLE FOR GUIDE

Section Length : 500 feet
Interest Rate : 8.00 % Inflation Rate : 6.00 %

Alternative : REPLACE IN TWO YEARS
Life of Alternative : 25

M&R ACTIVITY	YEAR	COST($)	PRESENT VALUE($)
REPAIR	1990	800.00	800.00
	Total:	800.00	800.00
REPAIR	1991	800.00	785.19
2ND REPAIR	1991	800.00	785.19
	Total:	1600.00	1570.37
REPLACE PIPE	1992	53900.00	51922.19
	Total:	53900.00	51922.19

Initial Cost ($) :	800.00
Present Value ($) :	54292.56
Equivalent Uniform Annual Cost (EUAC) :	5086.06
EUAC per Linear Foot :	10.17

ECON1 REPORT
REPORT DATE: 1990.03.08   13:41:50

PROJECTED COST ANALYSIS   (DETAIL)

Section ID   :EXAMPLE FOR GUIDE

Section Length   :   500 feet
Interest Rate   :   8.00 %   Inflation Rate   :   6.00 %

Alternative   : REPLACE IN 3RD YEAR
Life of Alternative : 25

M&R ACTIVITY	YEAR	COST($)	PRESENT VALUE($)
REPAIR	1990	800.00	800.00
	Total:	800.00	800.00
REPAIR	1991	800.00	785.19
2ND REPAIR	1991	800.00	785.19
	Total:	1600.00	1570.37
REPAIR	1992	800.00	770.64
2ND REPAIR	1992	800.00	770.64
3RD REPAIR	1992	800.00	770.64
	Total:	2400.00	2311.93
REPLACE PIPE	1993	53900.00	50960.67
	Total:	53900.00	50960.67

Initial Cost ($)   :   800.00
Present Value ($)   :   55642.97
Equivalent Uniform Annual Cost (EUAC) :   5212.57
EUAC per Linear Foot   :   10.43

APPENDIX C: ANSI PIPE SCHEDULES

Nominal	Actual Pipe	Wall Thickness (in.)	
Pipe Size	OD (in.)	Schedule 40	Schedule 80
1/2	0.84	0.109	0.147
3/4	1.050	0.113	0.154
1	1.315	0.133	0.179
1-1/4	1.660	0.140	0.191
1-1/2	1.900	0.145	0.200
2	2.375	0.154	0.218
2-1/2	2.875	0.203	0.276
3	3.5	0.216	0.300
3-1/2	4.0	0.226	0.318
4	4.5	0.237	0.337
5	5.563	0.258	0.375
6	6.625	0.280	0.432
8	8.625	0.322	0.500

The guide specification for gas distribution lines is CEGS-02711.

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ATTN: EUSA-HHC-CFC/Engr

USA Japan (USARJ)
ATTN: DCSEN 96343
ATTN: Facilities Engineer 96343
ATTN: DEH-Okinawa 96331

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10996
ATTN: Facilities Engineer

AMC - Dir., Inst., & Svcs.
ATTN: DEH (22)

FORSCOM
FORSCOM Engineer, ATTN: Spt Det. 15071

HSC
Walter Reed AMC 20307
ATTN: Facilities Engineer

INSCOM - Ch, Instl. Div.
Ft. Belvoir, VA 22060
ATTN: Engr & Hsg Div
Vint Hill Farms Station 22186
ATTN: IAV-DEH

HQ US Army Engr Activity, CA
ATTN: DEH
Cameron Station (3) 22314
Fort Lesley J. McNair 20319
Fort Meyer 22211

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac, Div. 48090

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AFESC/Engineering & Service Lab

NAVFAC
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National Guard Bureau 20310
Installation Division

US Army Env. Hygiene Agency
ATTN: HSHB-ME 21010

American Public Works Association 60637

Nat'l Institute of Standards & Tech 20899

Defense Technical Info. Center 22304
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